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Maeda et al.

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(45) **Date of Patent: Dec. 22, 2020**

(54) **IONIC WIND DELIVERY DEVICE**

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B60H 3/00 (2006.01)
F24F 13/06 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B60H 3/0071*** (2013.01); ***B03C 3/68*** (2013.01); ***B60H 1/00742*** (2013.01);
(Continued)

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CPC .. B03C 3/00; B03C 3/025; B03C 3/12; B03C 3/66; B03C 3/68; B60H 3/0071;
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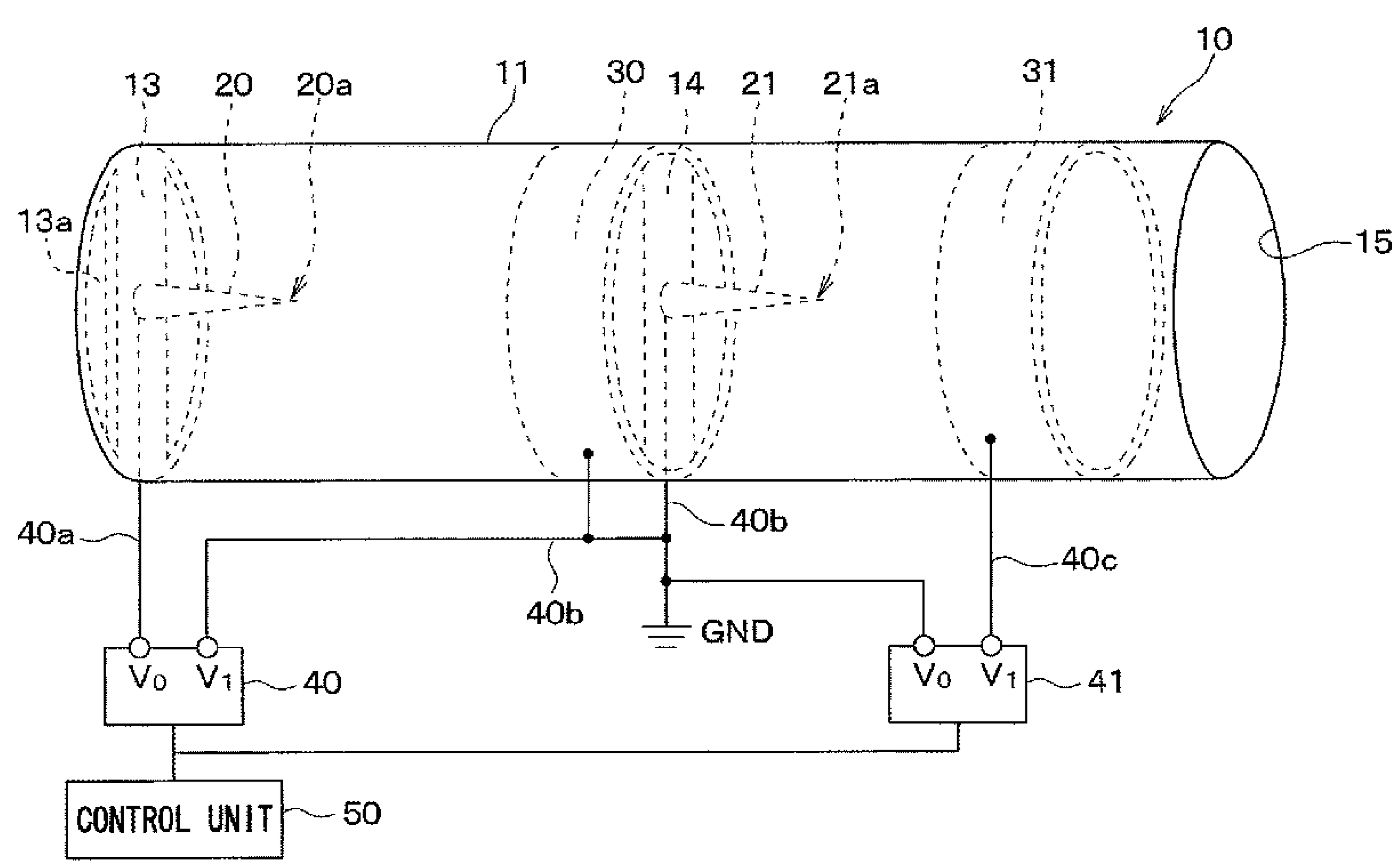
(57) **ABSTRACT**

An ionic wind delivery device includes a first discharge electrode; a reference electrode arranged separate from the first discharge electrode; a first power supply circuit configured to output a voltage to induce a corona discharge between the first discharge electrode and the reference electrode; a control electrode arranged on a delivery path of an ionic wind of ions that are generated by the corona discharge induced between the first discharge electrode and the reference electrode; a second discharge electrode arranged between the reference electrode and the control electrode; and a second power supply circuit configured to output a voltage to accelerate the ions generated by the
(Continued)



corona discharge induced between the first discharge electrode and the reference electrode and to induce a corona discharge between the second discharge electrode and the control electrode.

11 Claims, 11 Drawing Sheets

(51) **Int. Cl.**

H01T 19/04	(2006.01)
H01T 23/00	(2006.01)
B60H 1/00	(2006.01)
B03C 3/68	(2006.01)
F24F 3/16	(2006.01)

(52) **U.S. Cl.**

CPC ***F24F 13/06*** (2013.01); ***H01T 19/04*** (2013.01); ***H01T 23/00*** (2013.01); *F24F 2003/1682* (2013.01); *F24F 2013/0612* (2013.01)

(58) **Field of Classification Search**

CPC ... F24F 3/166; F24F 2003/1682; H01T 19/04; H01T 23/00

See application file for complete search history.

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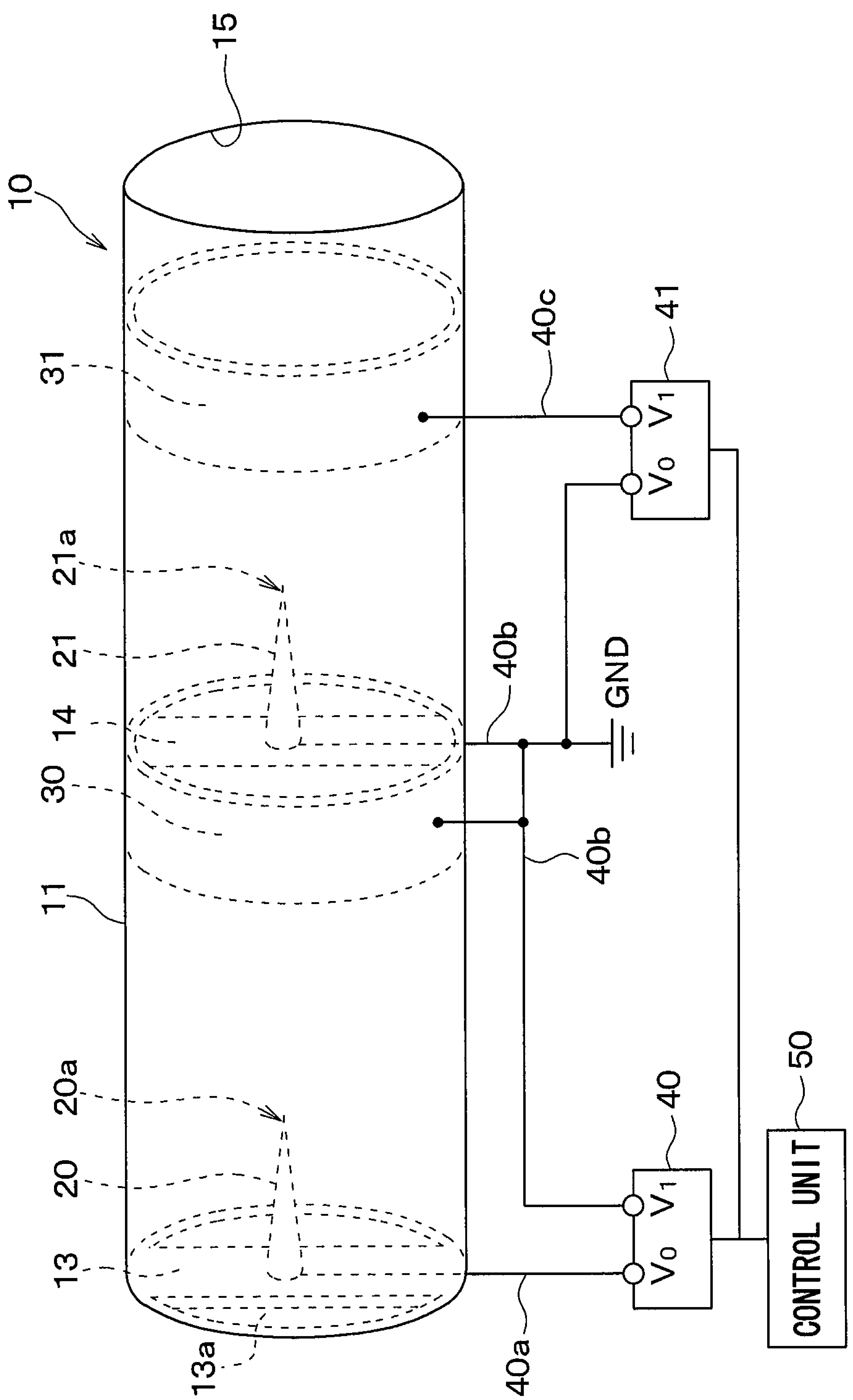

10
15
31
21a
21
14
30
11
20a
20
13
13a
40a
40b
40b
40c
41
40
50
GND
V_0
V_1
V_0
V_1
CONTROL UNIT

FIG. 1

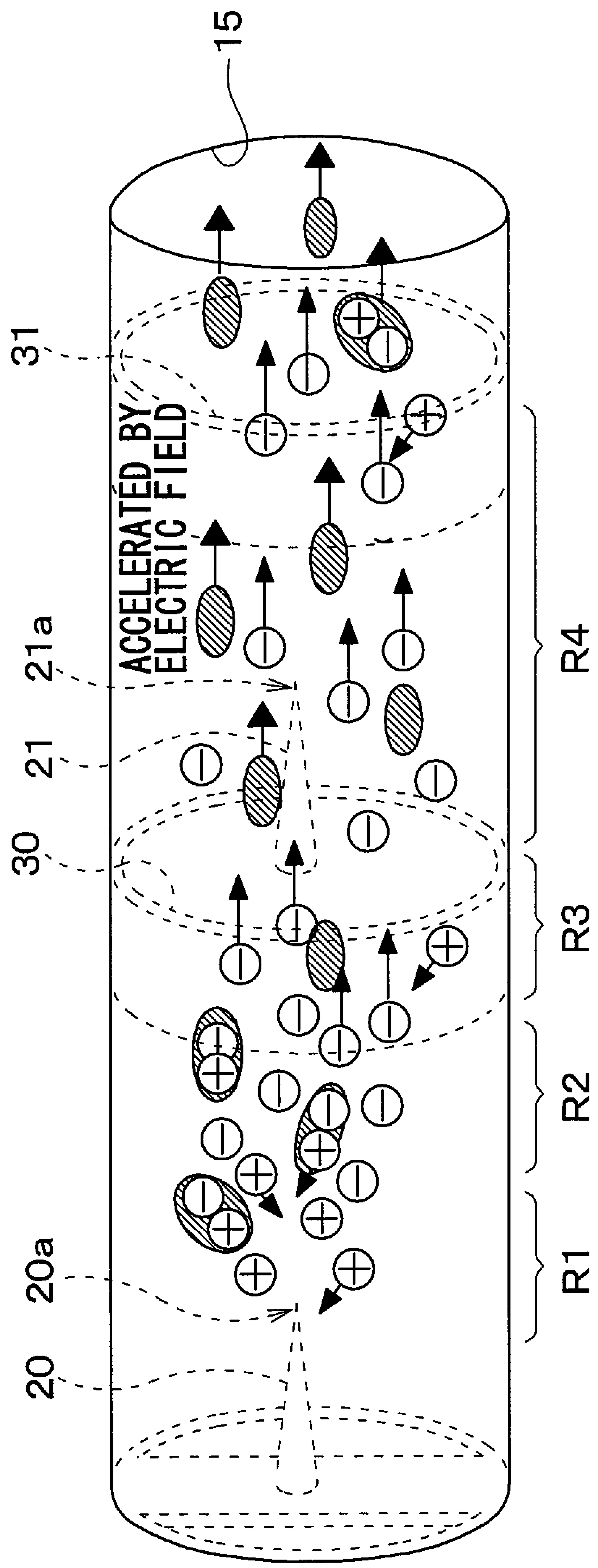
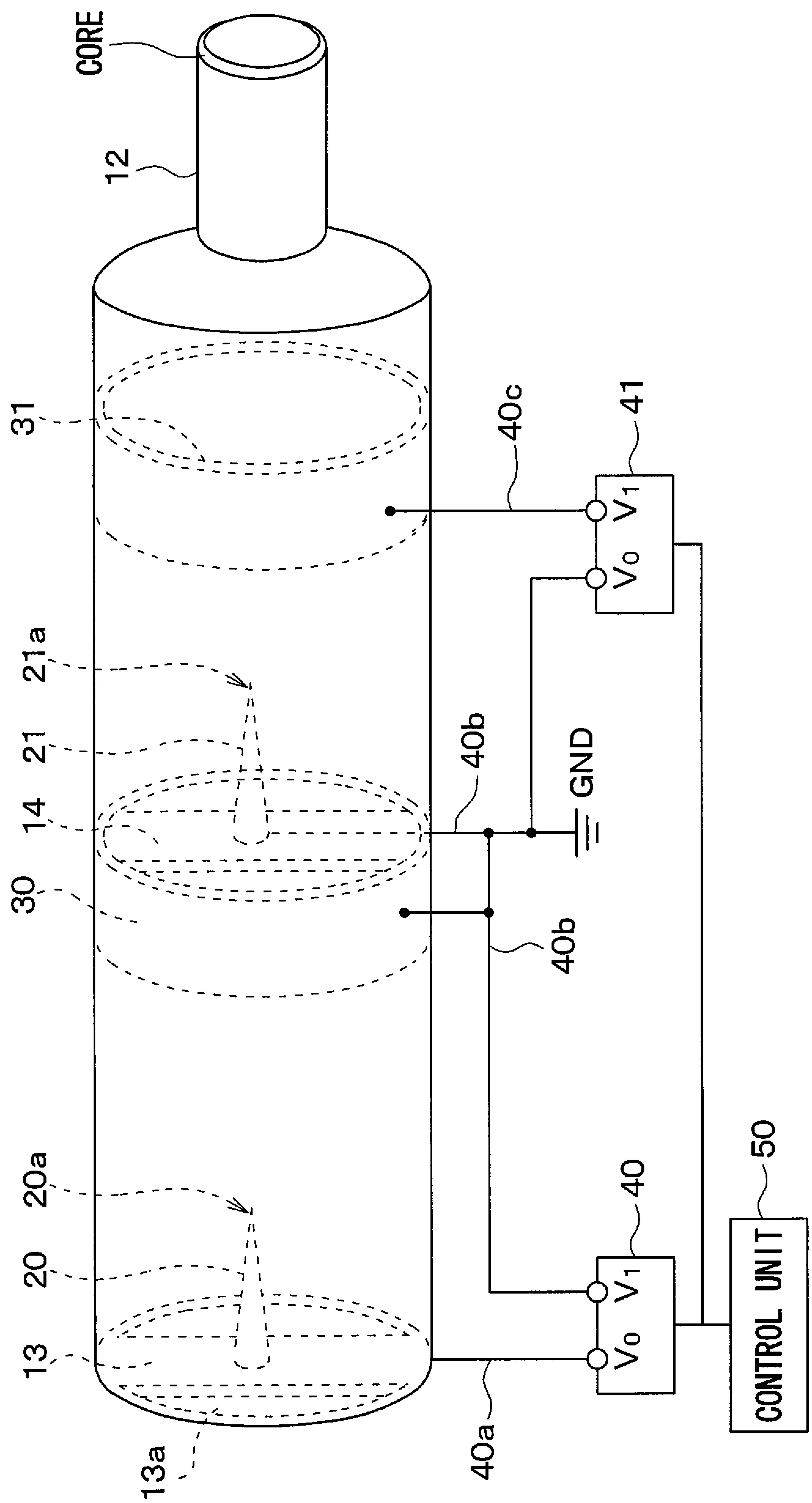

15
31
ACCELERATED BY ELECTRIC FIELD
21a
21
30
20a
20
R1
R2
R3
R4

FIG. 2

FIG. 3


CORE
12
31
40c
41
V_1
V_0
21a
21
14
30
40b
GND
40b
20a
20
13
13a
40
V_1
V_0
40a
50
CONTROL UNIT

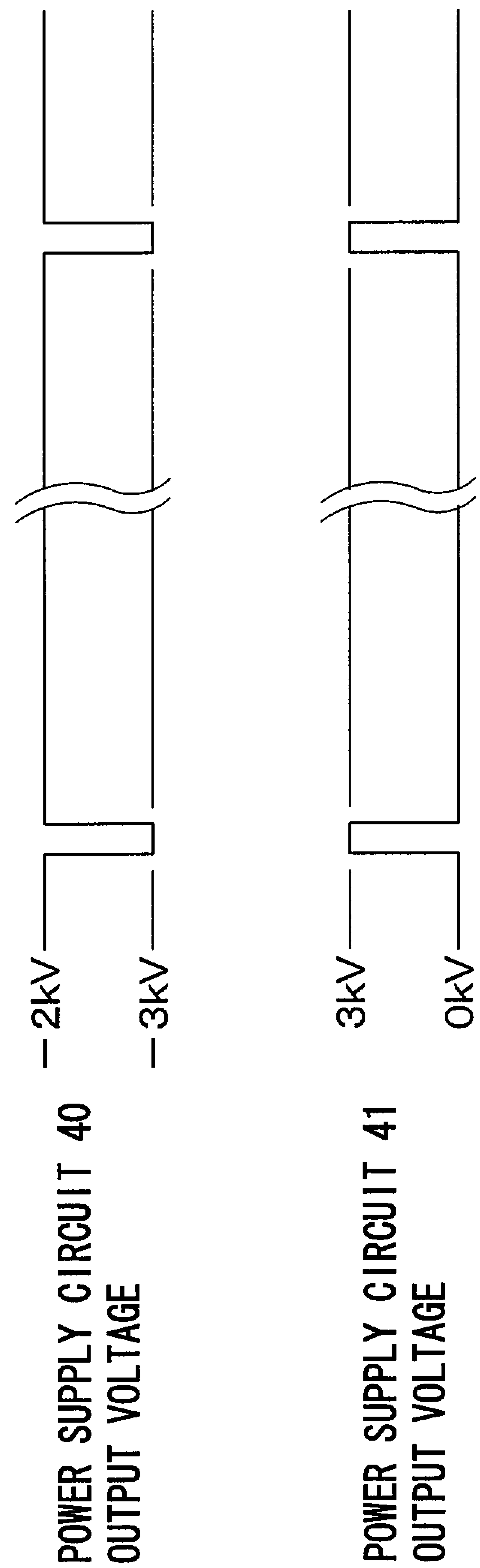

POWER SUPPLY CIRCUIT 40
OUTPUT VOLTAGE
-2kV
-3kV
POWER SUPPLY CIRCUIT 41
OUTPUT VOLTAGE
3kV
0kV

FIG. 4

FIG. 5

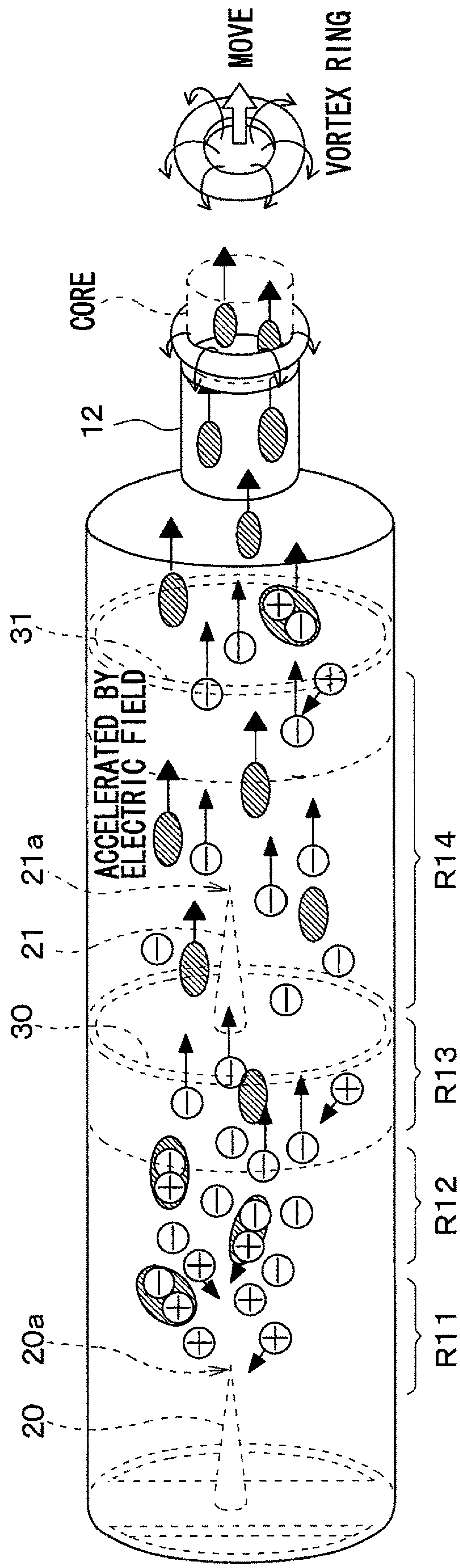
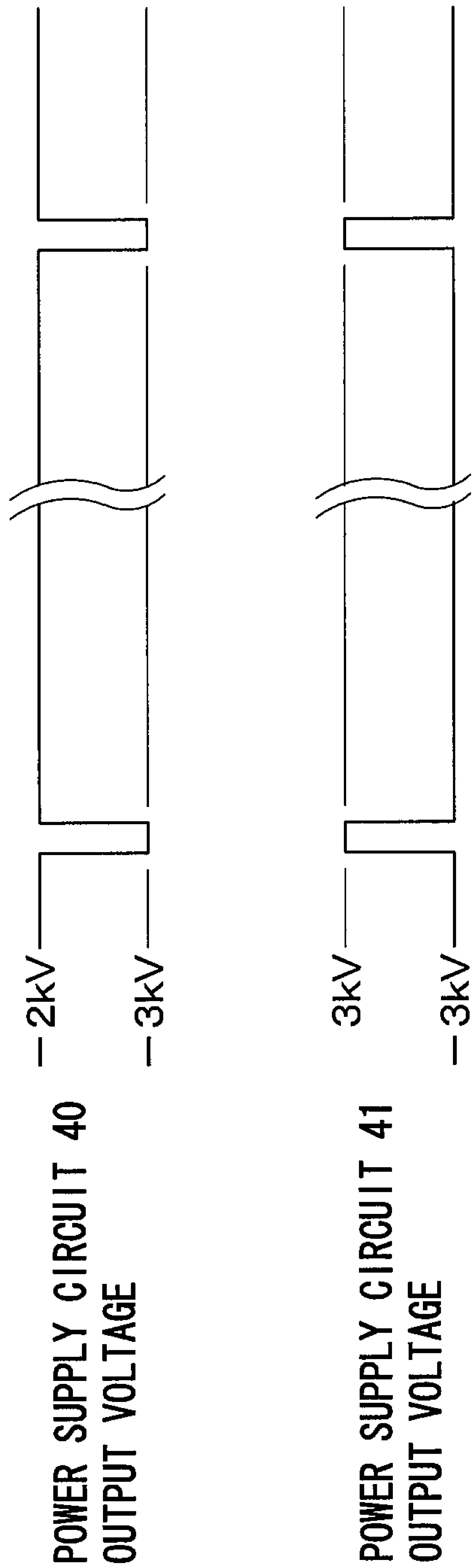

MOVE
VORTEX RING
CORE
12
31
ACCELERATED BY ELECTRIC FIELD
21a
21
30
20a
20
R14
R13
R12
R11

FIG. 6


POWER SUPPLY CIRCUIT 40
OUTPUT VOLTAGE
2kV
-3kV
POWER SUPPLY CIRCUIT 41
OUTPUT VOLTAGE
3kV
-3kV

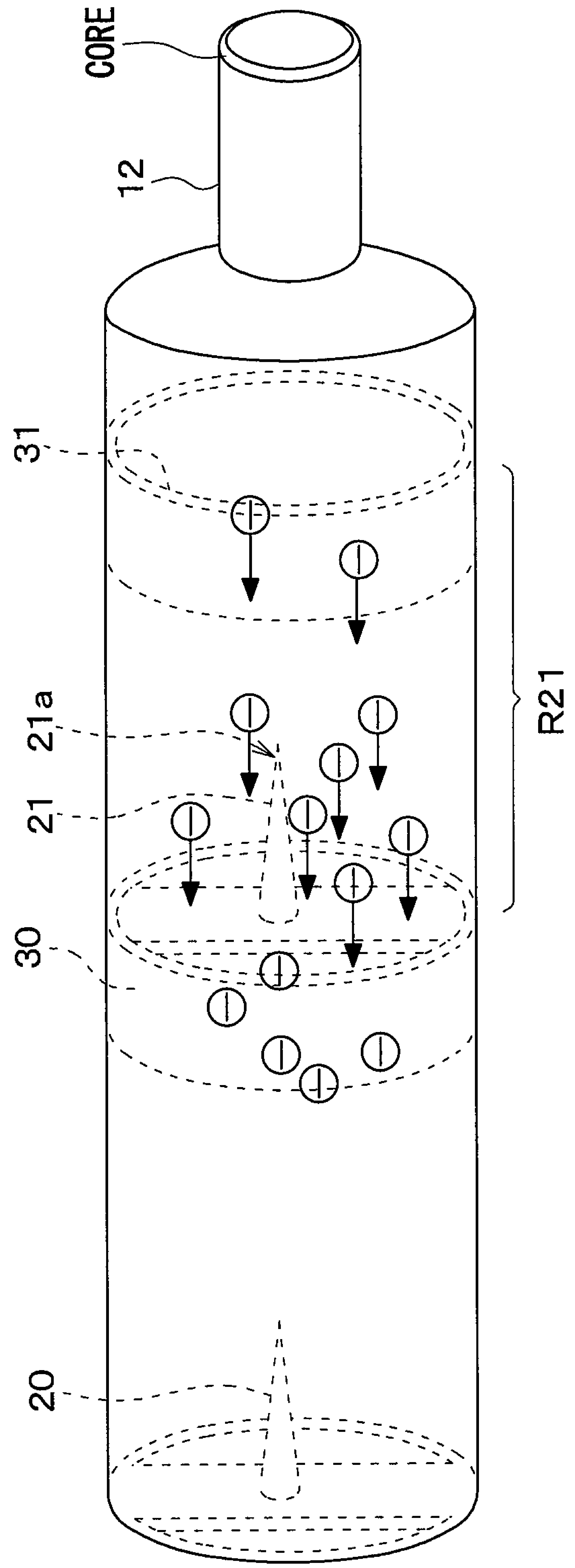


FIG. 7

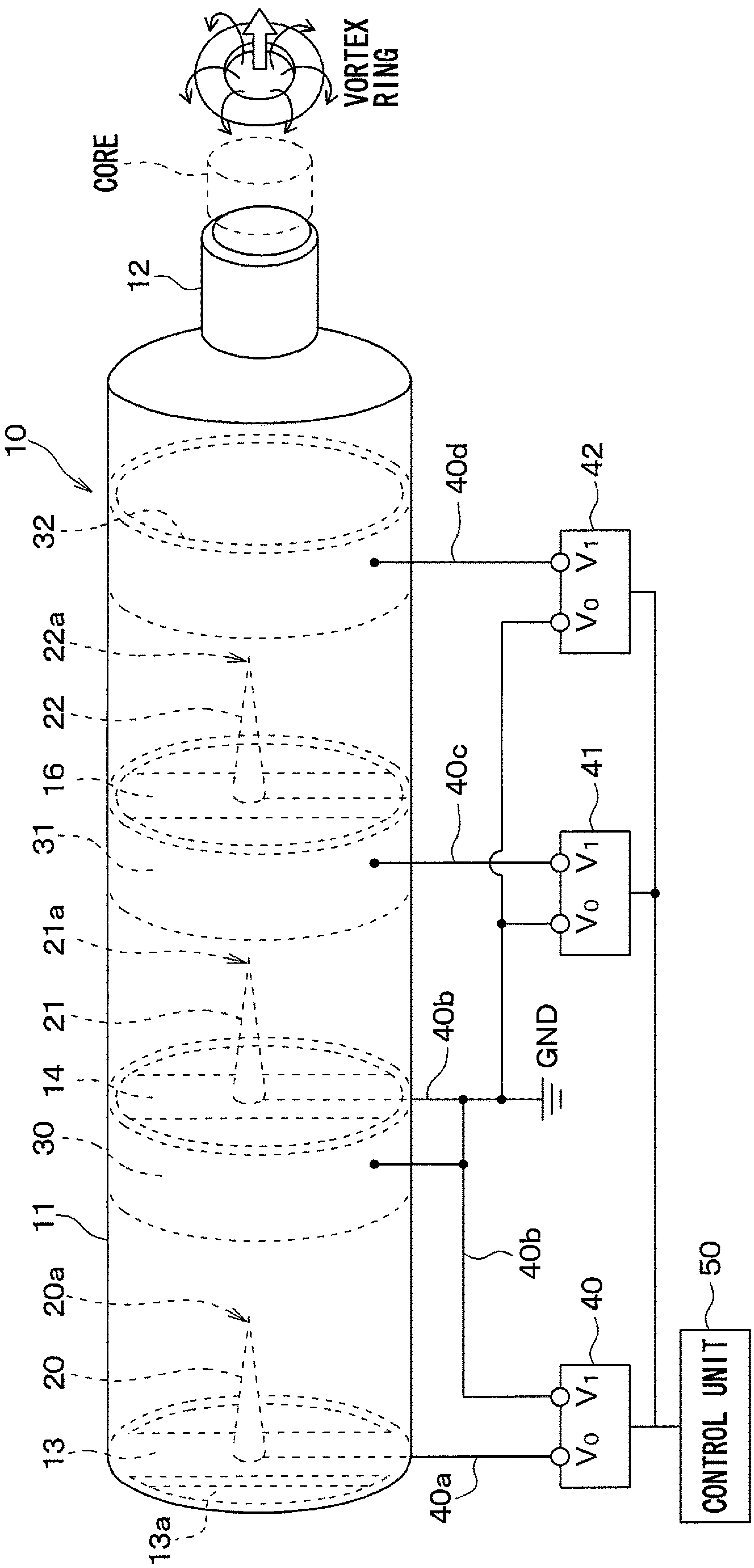

VORTEX RING
CORE
12
10
32
22a
22
16
31
21a
21
14
30
11
20a
20
13
13a
40a
40b
40b
40c
40d
GND
40
41
42
V_0
V_1
50
CONTROL UNIT

FIG. 8

FIG. 9

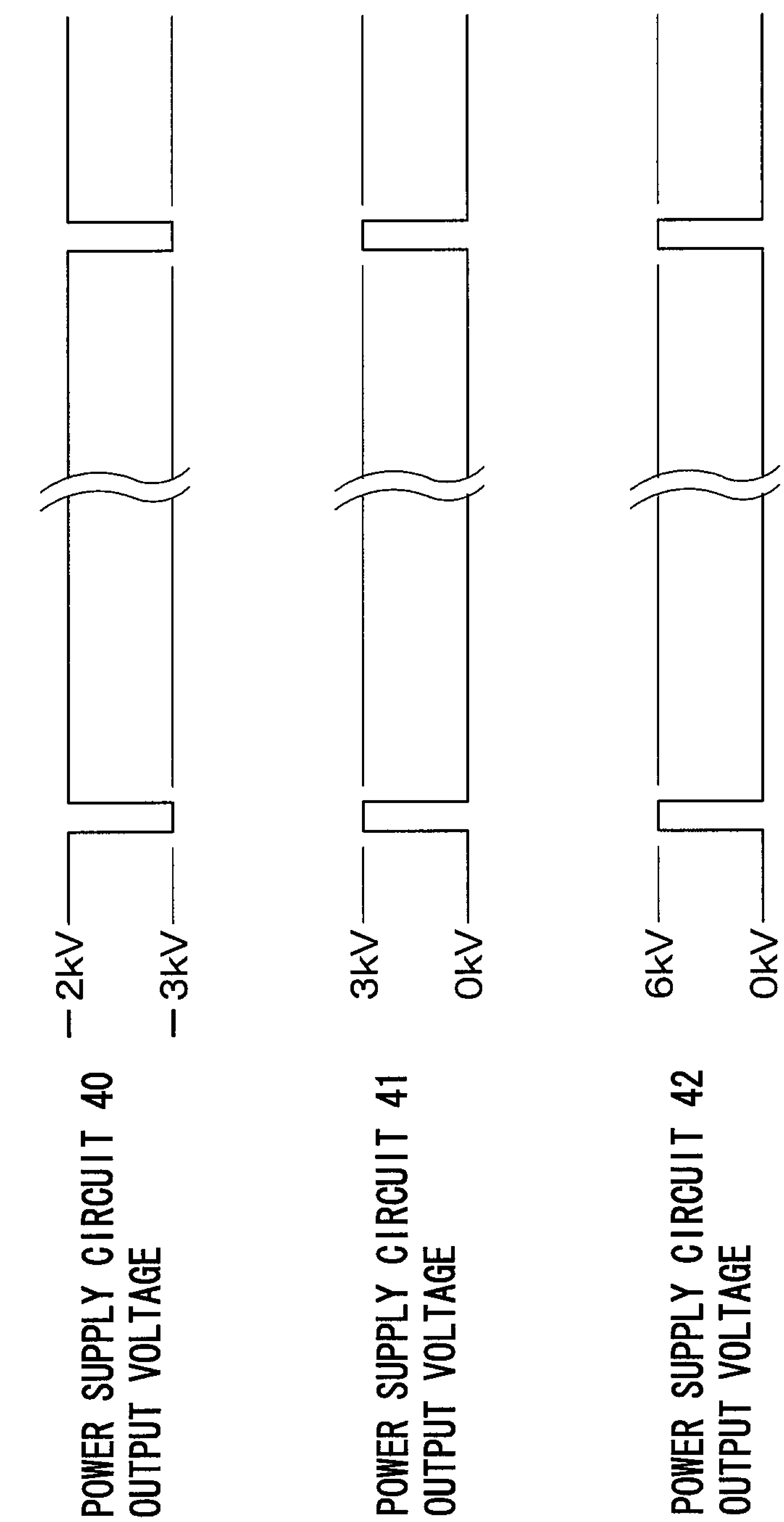

POWER SUPPLY CIRCUIT 40
OUTPUT VOLTAGE
−2kV
−3kV
POWER SUPPLY CIRCUIT 41
OUTPUT VOLTAGE
3kV
0kV
POWER SUPPLY CIRCUIT 42
OUTPUT VOLTAGE
6kV
0kV

FIG. 10

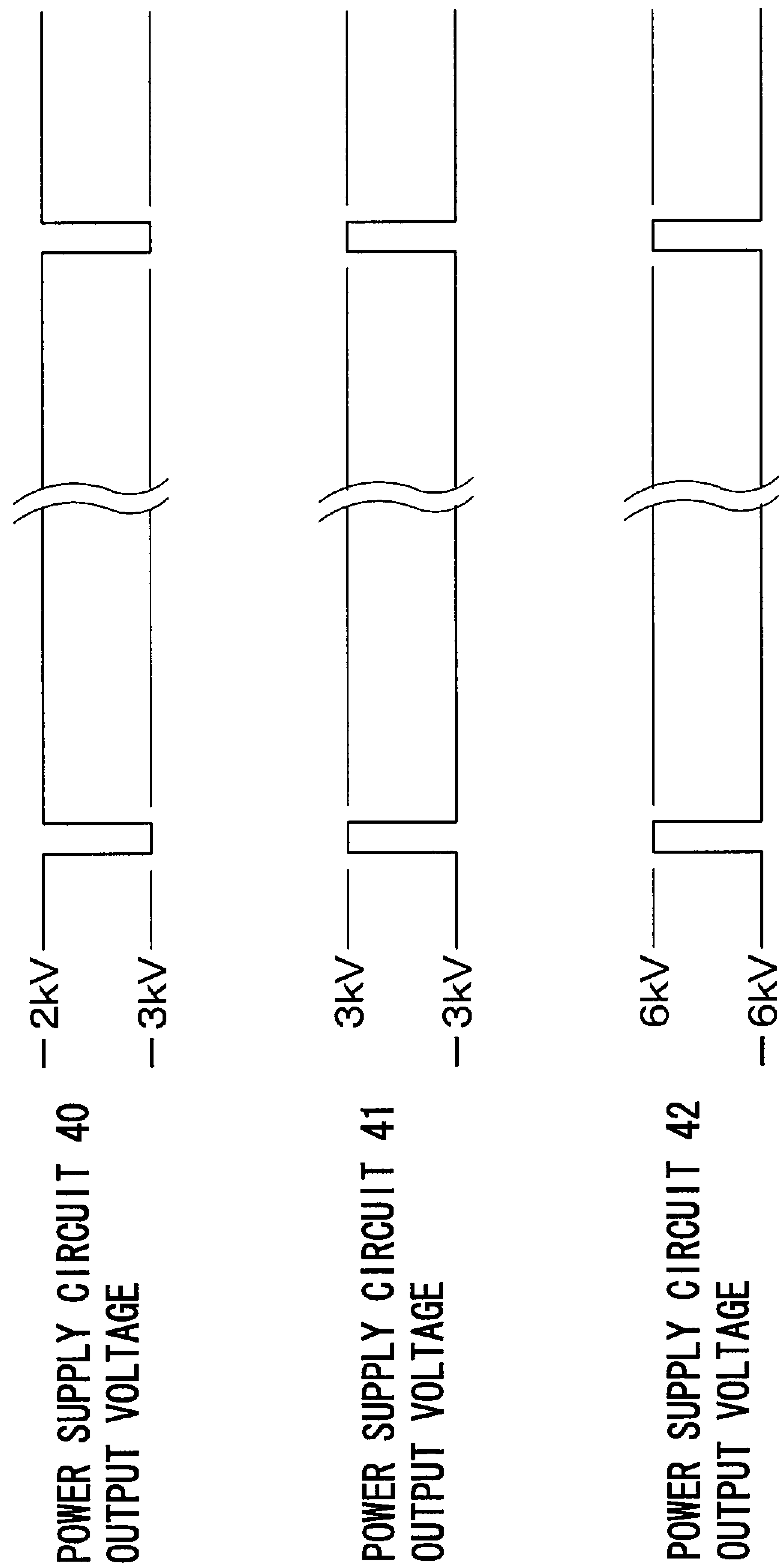
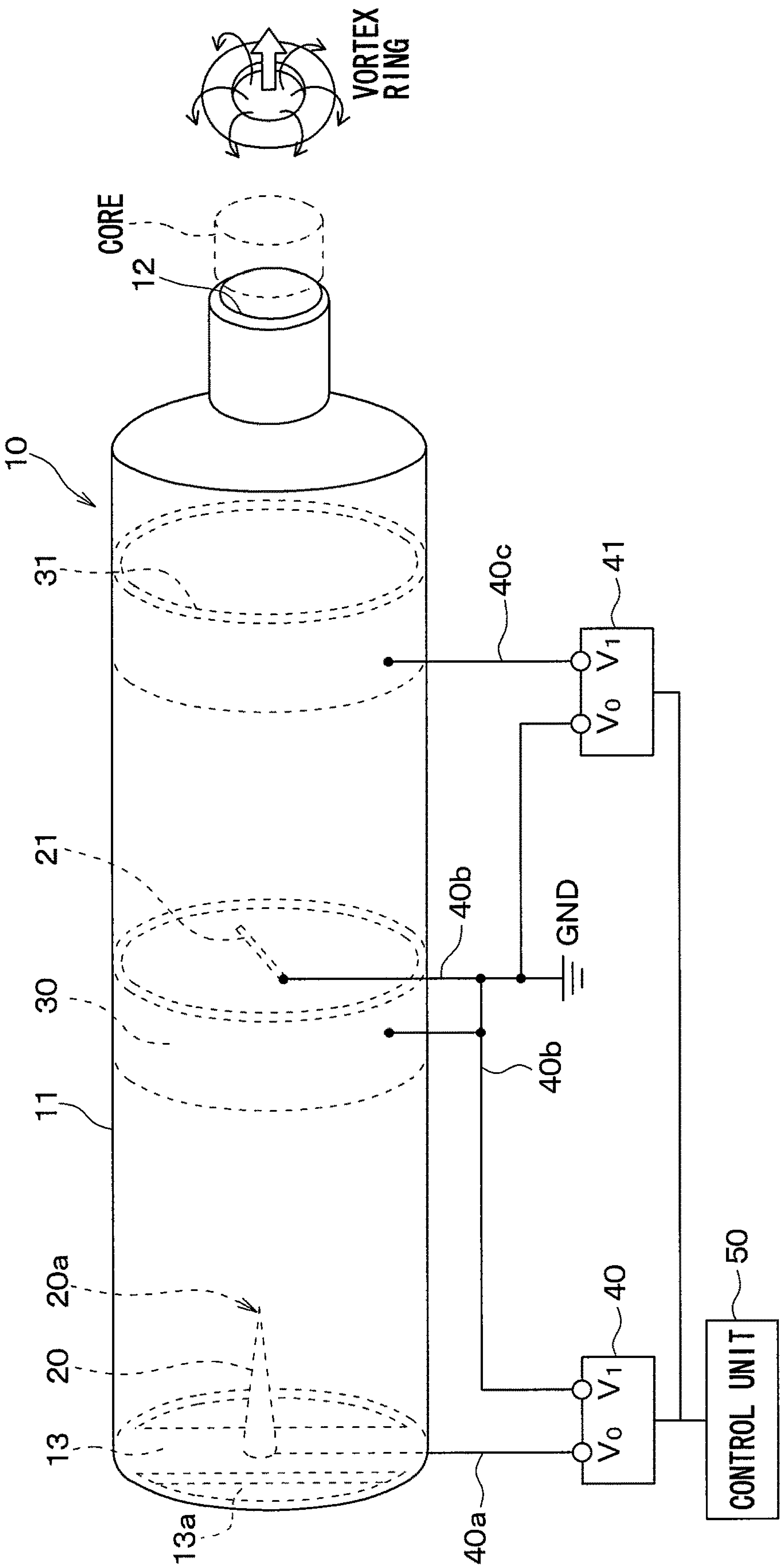

POWER SUPPLY CIRCUIT 40
OUTPUT VOLTAGE
-2kV
-3kV
POWER SUPPLY CIRCUIT 41
OUTPUT VOLTAGE
3kV
-3kV
POWER SUPPLY CIRCUIT 42
OUTPUT VOLTAGE
6kV
-6kV

FIG. 11


VORTEX RING
CORE
12
10
31
40c
41
V_1
V_0
21
40b
GND
30
11
40b
50
CONTROL UNIT
40
V_1
V_0
20a
20
13
13a
40a

IONIC WIND DELIVERY DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Phase Application under 35 U.S.C. 371 of International Application No. PCT/JP2016/072186 filed on Jul. 28, 2016 and published in Japanese as WO 2017/029962 A1 on Feb. 23, 2017. This application is based on and claims the benefit of priority from Japanese Patent Application No. 2015-162069 filed on Aug. 19, 2015. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to an ionic wind delivery device that deliveries an ionic wind.

BACKGROUND ART

Patent Literature 1 discloses an ionic wind delivery device that emits a jet of an ionic wind from a jet opening of a case to the outside of a case. In the ionic wind delivery device, the case has an air introducing opening on an end, and an air jet opening on the other end. Multiple electrode pairs, each including a needle-like discharge electrode and a tubular reference electrode, are arranged in series inside of the case. An ionic wind is generated as corona discharge continuously occurs between the discharge electrodes and the reference electrodes of the respective electrode pairs. The ionic wind is emitted out as a jet stream to the outside of the case from the jet opening.

PRIOR ART LITERATURE

Patent Literature

Patent Literature 1: U.S. Pat. No. 7,911,146 B2

SUMMARY OF INVENTION

In the device disclosed in the Patent Literature 1, each of the discharge electrodes has a negative electric potential, and each of the reference electrodes is grounded. Therefore, the electric field is reversed in between the electrode pairs, such as between the electrode pair on the first stage and the electrode pair on the second stage, or between the electrode pair on the second stage and the electrode pair on the third stage. As a result, acceleration of ions is disturbed, and thus it is difficult to favorably accelerate the ionic wind.

It is an object of the present disclosure to provide an ionic wind delivery device capable of further accelerating an ionic wind.

According to an aspect of the present disclosure, an ionic wind delivery device includes: a first discharge electrode; a reference electrode arranged separate from the first discharge electrode; a first power supply circuit configured to generate a voltage to induce a corona discharge between the first discharge electrode and the reference electrode; a control electrode arranged on a delivery path of an ionic wind of ions generated by the corona discharge induced between the first discharge electrode and the reference electrode; a second discharge electrode arranged between the reference electrode and the control electrode; and a second power supply circuit configured to output a voltage that accelerates the ions generated by the corona discharge induced between

the first discharge electrode and the reference electrode, and induces corona discharge between the second discharge electrode and the control electrode.

In such a configuration, the control electrode is arranged on the delivery path of the ionic wind of ions generated by the corona discharge induced between the first discharge electrode and the reference electrode. By the second power supply circuit, the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode are accelerated, as well as the ions are added to the accelerated ions due to the corona discharge induced between the second discharge electrode and the control electrode. Accordingly, the ionic wind can be further accelerated.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating a structure of an ionic wind delivery device according to a first embodiment;

FIG. **2** is a diagram for explaining generation of an ionic wind;

FIG. **3** is a diagram illustrating a structure of an ionic wind delivery device according to a second embodiment;

FIG. **4** is a diagram illustrating waveforms of outputs of power supply circuits of a jet stream generation device according to the second embodiment;

FIG. **5** is a diagram for explaining generation of a jet stream;

FIG. **6** is a diagram illustrating waveforms of outputs of power supply circuits of a jet stream generation device according to a third embodiment;

FIG. **7** is a diagram for explaining accumulation of ions;

FIG. **8** is a diagram illustrating a structure of an ionic wind delivery device according to a fourth embodiment;

FIG. **9** is a diagram illustrating waveforms of outputs of power supply circuits of a jet stream generation device according to the fourth embodiment;

FIG. **10** is a diagram illustrating waveforms of outputs of power supply circuits of a jet stream generation device according to the fifth embodiment; and

FIG. **11** is a diagram for explaining a modification.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. Portions that are the same or equivalent in the respective embodiments are shown with the same reference numbers in the drawings.

First Embodiment

A structure of an ionic wind delivery device according to a first embodiment is shown in FIG. **1**. The ionic wind delivery device is attached to a meter device or the like of a vehicle to emit a jet stream and deliver an air vortex ring toward a passenger's face of the vehicle, to thereby enhance comfort.

The ionic wind delivery device includes a case **10**, a first discharge electrode **20**, a reference electrode **30**, a second discharge electrode **21**, a control electrode **31**, a power supply circuit **40**, a power supply circuit **41**, and a control unit **50**. In FIG. **1**, the case **10** is illustrated as transparent so as to show the interior of the case **10**.

The case **10** accommodates the first discharge electrode **20**, the reference electrode **30**, the second discharge electrode **21** and the control electrode **31** therein. The case **10** has a hollow cylindrical body portion **11** and a support portion **13**. The body portion **11** and the support portion **13** are provided by insulating members.

The body portion **11** is formed with an opening **13***a* for drawing air outside of the case **10** into the case **10** and the support portion **13** for supporting the first discharge electrode **20**, at an end in a longitudinal direction of the body portion **11**. The body portion **11** is formed with an opening **15** at the other end in the longitudinal direction. Also, the control electrode **31**, which is made of a conductive metal, is disposed at the other end of the body portion **11**. The reference electrode **30** is disposed between the first discharge electrode **20** and the control electrode **31**.

The first discharge electrode **20** has a needle-shaped end portion **20***a*. The first discharge electrode **20** is a member made of a conductive metal (for example, copper). The first discharge electrode **20** is supported by the support portion **13** so that the end portion **20***a* is located on an inner side of the case **10**. An insulating member, which is not shown, is provided between the first discharge electrode **20** and the case **10** to insulate the first discharge electrode **20** and the case **10** from each other.

The reference electrode **30** has a hollow cylindrical shape. The reference electrode **30** is arranged inside of the case **10** so that an outer surface of the reference electrode **30** is in contact with an inner surface of the case **10**.

The power supply circuit **40** serves as a first power supply circuit that generates an output voltage to control a potential difference between the first discharge electrode **20** and the reference electrode **30**. The power supply circuit **40** includes a first output terminal V_0 and a second output terminal V_1. The first output terminal V_0 of the power supply circuit **40** is connected to the first discharge electrode **20** through a wiring **40***a*. The second output terminal V_1 of the power supply circuit **40** is connected to the reference electrode **30** and a ground terminal GND through a wiring **40***b*. The power supply circuit **40** can generate not only an output voltage of equal to or greater than −3 kV and equal to or less than 3 kV, but also an output voltage of −3 kV or less and an output voltage of 3 kV or more. Also, the power supply circuit **40** can output a voltage having a rectangular waveform.

The second discharge electrode **21** has a needle-shaped end portion **20***a*. The second discharge electrode **21** is a member made of a conductive metal (for example, copper). A support portion **14** for supporting the second discharge electrode **21** is formed inside of the reference electrode **30** having the hollow cylindrical shape. The second discharge electrode **21** is supported by the support portion **14** formed inside of the reference electrode **30**. Since the second discharge electrode **21** is connected to the reference electrode **30**, the second discharge electrode **21** and the reference electrode **30** have the same potential.

The control electrode **31** has a hollow cylindrical shape. The control electrode **31** is a member made of a conductive metal (for example, copper). The reference electrode **30** is arranged inside of the case **10** so that an outer surface of the reference electrode **30** is in contact with an inner surface of the case **10**. The control electrode **31** serves as a first control electrode that is arranged on a delivery path of an ionic wind of ions generated by corona discharge induced between the first discharge electrode **20** and the reference electrode **30** flows.

The power supply circuit **41** serves as a second power supply circuit that generates an output voltage to control a potential difference between the second discharge electrode **21** and reference electrode **30** and the control electrode **31**. The power supply circuit **41** has a first output terminal V_0 and a second output terminal V_1. The first output terminal V_0 of the power supply circuit **41** is connected, through a wiring **40***b*, to the second discharge electrode **21**, the reference electrode **30**, the second output terminal V_1 of the power supply circuit **4**, and the ground terminal. The second output terminal V_1 of the power supply circuit **41** is connected to the control electrode **31** through a wiring **40***c*. The second output terminal V_1 and the case **10** are insulated from each other, and the first output terminal V_0 and the case **10** are insulated from each other.

The power supply circuit **41** can generate an output voltage of 6 kV or less. The power supply circuit **41** can output a voltage having a rectangular waveform.

The control unit **50** is configured as a computer including a CPU, a RAN, a ROM, and an I/O. The CPU executes various processing in accordance with a program stored in the ROM. The control unit **50** controls the output voltage of the power supply circuit **40**, and controls the output voltage of the power supply circuit **41**. Note that each of the RAM and the ROM is a non-transitory tangible storage medium.

Next, an operation of the ionic wind delivery device will be described with reference to FIGS. **2** and **3**. The control unit **50** controls the output voltage of the power supply circuit **40** so that a voltage to induce corona discharge between the first discharge electrode **20** and the reference electrode **30** is applied, and controls the output voltage of the power supply circuit **41** so that a voltage to induce corona discharge between the second discharge electrode **21** and the control electrode **31** is applied. That is, the control unit **50** controls the output voltage of the power supply circuits **40**, **41** to continuously induce the corona discharge between the first discharge electrode **20** and the reference electrode **30** as well as to continuously induce the corona discharge between the electrode **21** and the control electrode **31**. The voltage to induce the corona discharge between the first discharge electrode **20** and the reference electrode **30** is −3 kV in the present embodiment. The voltage to induce the corona discharge between the second discharge electrode **21** and the control electrode **31** is 3 kV in the present embodiment. Therefore, the potential of the first discharge electrode **20** is −3 kV, the potential of the reference electrode **30** is 0 V, and the potential of the control electrode **31** is +3 kV.

When the voltage of −3 kV is applied between the first discharge electrode **20** and the reference electrode **30**, as described above, a strong electric field occurs in the vicinity of the end portion **20***a* of the first discharge electrode **20**. Thus, as shown in a region R**1** of FIG. **2**, the corona discharge is induced on a periphery of the first discharge electrode **20**, and thus the corona discharge is generated between the first discharge electrode **20** and the reference electrode **30**.

Further, as shown in a region R**2** of FIG. **2**, air on the periphery of the first discharge electrode **20** is ionized due to an occurrence of the corona discharge, and thus air ions are generated. Specifically, the air on the periphery of the first discharge electrode **20** is ionized to generate positive ions and negative ions.

Further, as shown in a region R**3** of FIG. **2**, the negative ions are accelerated by an electric field between the electrodes and moved toward the reference electrode **30**. In this case, while the negative ions moves toward the reference electrode **30**, air on the periphery of the first discharge electrode **20** and air around the reference electrode **30** are involved to the negative ions. As a result, an ionic wind is generated. The ionic wind passes through the inside of the reference electrode **30**.

The potential of the reference electrode **30** is 0 V, and the potential of the control electrode **31** is 3 kV. Therefore, the negative ions having passed through the reference electrode **30** are accelerated while moving toward the control electrode **31**, as shown in a region R**4** of FIG. **2**. As a result, a larger ionic wind is generated. The ionic wind having passed through the control electrode **31** is emitted out from the opening **15** formed at the other end of the case **10**.

The potential of the second discharge electrode **21** is 0 V, and the potential of the control electrode **31** is 3 kV. Therefore, a strong electric field is generated in the vicinity of the end portion **21***a* of the second discharge electrode **21**, and the corona discharge is induced on a periphery of the second discharge electrode **21**. Thus, the corona discharge occurs between the second discharge electrode **21** and the control electrode **31**.

As described above, the corona discharge is induced not only between the first discharge electrode **20** and the reference electrode **30**, but also between the second discharge electrode **21** and the control electrode **31**.

Further, the air on the periphery of the second discharge electrode **21** is ionized, due to the occurrence of the corona discharge, so as to generate the positive ions and the negative ions. The negative ions are accelerated due to the electric field between the electrodes and moved toward the control electrode **31**. In this case, the negative ions that are generated due to the corona discharge occurred between the second discharge electrode **21** and the control electrode **31** also involve air on the periphery of the second discharge electrode **21** and air round the control electrode **31** while moving toward the control electrode **31**. As a result, the ionic wind occurs. The ionic wind that has passed through the control electrode **31** is blown out from the opening **15** formed at the other end of the case **10**.

In the structure described above, the control electrode **31** is arranged on the delivery path of the ionic wind of the ions that are generated by the corona discharge induced between the first discharge electrode **20** and the reference electrode **30**. Further, the ions generated between the first discharge electrode **20** and the reference electrode **30** are accelerated by the voltage output by the power supply circuit **41**. In addition, ions are added due to the corona discharge induced between the second discharge electrode **21** and the control electrode **31**. Accordingly, the ionic wind can be further accelerated.

Second Embodiment

Next, an ionic wind delivery device according to a second embodiment will be described with reference to FIGS. **3**, **4** and **5**. The ionic wind delivery device of the present embodiment has a different structure from the ion delivery device of the first embodiment as the case **10** has a jet nozzle **12**. The jet nozzle **12** corresponds to a jet opening.

The case **10** has the jet nozzle **12** that has a tubular shape and emits a jet stream of the ionic wind of the ions generated by the corona discharge induced inside of the case **10**. Specifically, the case **10** has an opening **13***a* for drawing air outside of the case **10** into the case **10**, at an end of the body portion **11** with respect to the longitudinal direction of the body portion **11**. The jet nozzle **12** having the tubular shape is provided at the other end of the body portion **11** with respect to the longitudinal direction to emit the jet stream of the ionic wind of the ions generated due to the corona discharge. The nozzle **12** has a diameter smaller than the diameter of the body portion **11**. That is, the hydraulic diameter of an air passage in the jet nozzle **12** is smaller than the hydraulic diameter of an air passage in the body part **11**.

In the first embodiment described above, the corona discharge is continuously induced between the first discharge electrode **20** and the reference electrode **30**, as well as the corona discharge is continuously induced between the second discharge electrode **21** and the control electrode **31**. In the present embodiment, on the other hand, the corona discharge is intermittently induced synchronously between the first discharge electrode **20** and the reference electrode **30** and between the second discharge electrode **21** and the control electrode **31**.

Next, an operation of the ionic wind delivery device of the present embodiment will be described. Firstly, as shown in FIG. **4**, the control unit **50** controls the power supply circuit **40** to output the voltage of −2 kV from the power supply circuit **40**. As a result, the first discharge electrode **20** has the potential of −2 kV, and the reference electrode **30** has the potential of 0 V. In this case, even when the output voltage of the power supply circuit **40** is −2 kV, corona discharge does not occur on the periphery of the first discharge electrode **20**.

At the same time, the control unit **50** controls the power supply circuit **41** so that the output voltage of the power supply circuit **41** is 0 V. As a result, each of the second discharge electrode **21**, the control electrode **31** and the reference electrode **30** has the potential of 0 V. Therefore, corona discharge does not occur on the periphery of the second discharge electrode.

Next, as shown in FIG. **4**, the control unit **50** controls the power supply circuit **40** and the power supply circuit **41** so that the power supply circuit **40** outputs the voltage of −3 kV for a fixed period of time, and the power supply circuit **41** outputs the voltage of 3 kV for the same fixed period of time. In the present embodiment, the fixed period of time is 0.2 seconds. The control unit **50** controls the power supply circuit **40** and the power supply circuit **41** so that the output voltage of the power supply circuit **40** and the output voltage of the power supply circuit **41** are switched simultaneously. As a result, the potential of the first discharge electrode **20** is −3 kV, and the potentials of the second discharge electrode **21** and the reference electrode **30** are 0 V, and the potential of the control electrode **31** is 3 kV.

As described above, when the voltage of −3 kV is applied between the first discharge electrode **20** and the reference electrode **30**, a strong electric field is generated in the vicinity of the end portion **20***a* of the first discharge electrode **20**. As a result, as shown in a region R**11** of FIG. **5**, coronal discharge is induced on a periphery of the first discharge electrode **20**, and thus the corona discharge is induced between the first discharge electrode **20** and the reference electrode **30**.

As shown in a region R**12** of FIG. **5**, air on the periphery of the first discharge electrode **20** is ionized due to the occurrence of the corona discharge, and thus air ions are generated. Specifically, the air on the periphery of the first discharge electrode **20** is ionized, and thus positive ions and negative ions are generated.

Further, as shown in a region R**13** of FIG. **5**, the negative ions are accelerated by the electric field between the electrodes, and moved toward the reference electrode **30**. As shown in a region R**14** of FIG. **5**, air on the periphery of the first discharge electrode **20** and air around the reference electrode **30** are involved in the negative ions while the negative ions are moved toward the reference electrode **30**. As a result, an ionic wind is generated.

In addition, since the potential of the control electrode **31** is 3 kV, and the potential of the reference electrode **30** is 0 V, the negative ions having passed through the reference electrode **30** are accelerated while moving toward the control electrode **31**. As a result, a larger ionic wind is generated. The ionic wind having passed through the control electrode **31** is blown out as a jet stream from the jet nozzle **12**.

In this case, a core of a cylindrical air jet stream is blown out from the jet nozzle **12**. The core of the air jet stream blown out from the jet nozzle **12** forms a vortex ring due to friction with surrounding air that is stationary. In this way, the vortex ring of air is generated.

A part of the negative ions inside of the case **10** is absorbed through the ground terminal GND. An another part of the negative ions inside of the case **10** stays inside of the case **10** in a state of ions. A further another part of the negative ion inside of the case **10** is emitted out, together with a peripheral air, from the jet nozzle **12** to the outside of the case **10**.

The potential of the second discharge electrode **21** is 0 V, and the potential of the control electrode **31** is 3 kV. Therefore, a strong electric field is generated in the vicinity of the end portion **21***a* of the second discharge electrode **21**, and corona discharge is induced also on the periphery of the second discharge electrode **21**. Thus, the corona discharge is generated also between the second discharge electrode **21** and the control electrode **31**, and thus the negative ions are added. The negative ions added are also accelerated while moving toward the control electrode **31**. As a result, a larger ionic wind is generated. The ionic wind accelerated as described above is emitted out as a jet stream from the jet nozzle **12** to the outside of the case **10**.

In the present embodiment, the advantageous effects similar to the first embodiment can be achieved by the structures that are common to the first embodiment.

The ionic air delivery device includes a case **10** and a control unit **50**. The case **10** accommodates the control electrode **31**, and has the jet nozzle **12**. The jet nozzle **12** emits out, as a jet stream, the ionic wind of the ions generated by the corona discharge induced between the second discharge electrode **21** and the control electrode **31**, together with the ionic wind of the ions generated by the corona discharge induced between the first discharge electrode **20** and the reference electrode **30**. The control unit **50** controls the power supply circuit **41** so that the output voltage of the power supply circuit **41** is switched between a voltage that does not induce the corona discharge between the second discharge electrode **21** and the control electrode **31**, and a voltage that induce the corona discharge between the second discharge electrode **21** and the control electrode **31**.

In such a configuration, the ionic wind of the negative ions generated by the corona discharge induced between the second discharge electrode **21** and the control electrode **31** can be emitted out from the jet nozzle **12** of the case **10** as a jet stream.

The control unit **50** controls the power supply circuit **40** and the power supply circuit **41** so that, in the entirety of the period of time where the output voltage of the power supply circuit **41** is switched to and kept to the voltage that does not induce the corona discharge between the second discharge electrode **21** and the control electrode **31**, the output voltage of the power supply circuit **40** is switched to and kept to the voltage that does not induce the corona discharge between the first discharge electrode **20** and the reference electrode **30**. Further, the control unit **50** controls the power supply circuit **40** and the power supply circuit **41** so that, in the entirety of the period of time where the output voltage of the power supply circuit **41** is switched to and kept to the voltage that induce the corona discharge between the second discharge electrode **21** and the control electrode **31**, the output voltage of the power supply circuit **40** is switched to and kept to the voltage that induces the corona discharge between the first discharge electrode **20** and the reference electrode **30**.

As described above, the control unit **50** induces the corona discharges between the second discharge electrode **21** and the control electrode **31** and between the first discharge electrode **20** and the reference electrode **30**, in the entirety of the period of time where the output voltage of the power supply circuit **41** is switched to and kept to the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**. Therefore, a stronger jet stream can be emitted out from the jet nozzle **12** of the case **10**.

Third Embodiment

Next, an ionic wind delivery device according to a third embodiment will be described. The ionic wind delivery device of the third embodiment has the same structure as that of the ionic wind delivery device of the second embodiment described hereinabove.

In the second embodiment described hereinabove, the output voltage of the power supply circuit **41** is switched between 0 V and 3 kV. In the present embodiment, as shown in FIG. **6**, the output voltage of the power supply circuit **41** is switched between −3 kV and 3 kV. The control unit **50** controls the output voltage of the power supply circuit **41** so that ions present between the reference electrode **30** and the control electrode **31** are moved toward the reference electrode **30**, before controlling the output voltage of the power supply circuit **41** to a discharge voltage. The discharge voltage is a voltage to accelerate ions generated by corona discharge induced between the first discharge electrode **20** and the reference electrode **30**, as well as to induce corona discharge between the second discharge electrode **21** and the control electrode **31**. In the present embodiment, the discharge voltage is 3 kV. Specifically, the control unit **50** controls the power supply circuit **41** so that the output voltage of the power supply circuit **41** is controlled to −3 kV, before the output voltage of the power supply circuit **41** is controlled to the discharge voltage.

As a result, as shown in a region R**21** of FIG. **7**, negative ions present between the reference electrode **30** and the control electrode **31** is urged to move toward the reference electrode **30**, and is accumulated. Therefore, when the output voltage of the power supply circuit **41** is controlled next time so as to accelerate negative ions generated by the corona discharge toward a jet nozzle **12**, the negative ions are also accelerated while moving toward the control electrode **31**. Therefore, a larger ionic wind is generated, and blown out from the jet nozzle **12** as a jet stream. Namely, the velocity of the jet stream emitted out from the jet nozzle **12** can be increased, as compared with the jet stream generation device of the second embodiment described hereinabove. Further, the quantity of the negative ions emitted out as the jet stream from the jet nozzle **12** to the outside of the case **10** can be increased.

In the present embodiment, the advantageous effects similar to the second embodiment can be achieved by the structures that are common to the second embodiment.

The control unit **50** controls the power supply circuit **40** and the power supply circuit **41** so that the output voltage of the power supply circuit **40** is switched to the voltage that induces the corona discharge between the first discharge electrode **20** and the reference electrode **30**, as well as the output voltage of the power supply circuit **41** is switched to the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**. Further, the control unit **50** performs a predetermined control after the ionic wind of the ions generated by the corona discharges induced between the first discharge electrode **20** and the reference electrode **30** and between the second discharge electrode **21** and the control electrode **31** is emitted out as a jet stream from the jet nozzle **12**. In the predetermined control, the control unit **50** performs a returning control, before performing the discharge control again. In the discharge control, the power supply circuit **41** is controlled to output the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**. In the returning control, the power supply circuit **41** is controlled to output the voltage that urges ions present between the reference electrode **30** and the control electrode **31** to move toward the reference electrode **30**.

In such a configuration, the output voltage of the power supply circuit **41** is controlled so as to move the ions present between the reference electrode **30** and the control electrode **31** toward the reference electrode **30**. Therefore, the negative ions present between the reference electrode **30** and the control electrode **31** are moved toward the reference electrode **30** as being urged to return toward the reference electrode **30**, and are accumulated. Therefore, when the output voltage of the power supply circuit **41** is controlled so as to accelerate the negative ions toward the jet nozzle **12** again, the negative ions returned toward the reference electrode **30** are also accelerated while moving toward the control electrode **31**. As a result, the larger ionic wind is generated, and is blown out from the jet nozzle **12** as the jet stream. Namely, the velocity of the jet stream emitted out from the jet nozzle **12** can be further increased, as compared with the second embodiment.

Also in the present embodiment, similarly to the second embodiment, the core of the air jet stream having a tubular shape is blown out from the jet nozzle **12**. The core of the air jet stream blown out from the jet nozzle **12** forms the vortex ring due to the friction with the peripheral stationary air. In this way, the vortex air ring is generated.

Fourth Embodiment

An ionic wind delivery device according to a fourth embodiment will be described. FIG. **8** shows a structure of the ionic wind delivery device according to the present embodiment. The structure of the ionic wind delivery device of the present embodiment is different from the ionic wind delivery device of the second embodiment described above as further having a third discharge electrode **22**, a control electrode **32** and a power supply circuit **42**. The ionic wind delivery device of each of the first to third embodiments has a two-step electrode-pair structure in which an electrode pair made of the first discharge electrode **20** and the reference electrode **30** and an electrode pair made of the second discharge electrode **21** and the control electrode **31** are connected in series. On the other hand, the ionic wind delivery device of the present embodiment has a three-step electrode-pair structure that further includes an electrode pair made of a third electrode **22** and a control electrode **32**, the electrode pair being connected to the other two electrode pairs in series.

The third discharge electrode **22** has an end portion **22***a* having a needle shape, and is provided by a member made of a conductive metal (e.g., copper). The control electrode **31** has a hollow cylindrical shape. Inside of the control electrode **31**, a support portion **16** supporting the third discharge electrode **22** is formed. The third discharge electrode **22** is supported by the support portion **16** formed inside of the control electrode **31**. The third discharge electrode **22** is connected to the control electrode **31**. Thus, the third discharge electrode **22** and the control electrode **31** have the same potential.

The control electrode **32** has a hollow cylindrical shape. The control electrode **32** is provided by a member made of a conductive metal (e.g., copper). The control electrode **32** is disposed inside of the case **10** such that an outer surface of the control electrode **32** is in contact with an inner surface of the case **10**. The control electrode **32** is a second control electrode that is arranged on a delivery path of an ionic wind of ions generated by corona discharge induced between the second discharge electrode **21** and the control electrode **31**.

The power supply circuit **42** generates an output voltage to control a potential difference between the third discharge electrode **22** and control electrode **31** and the control electrode **32**. The power supply circuit **42** is a third power supply circuit that outputs a discharge voltage. The discharge voltage is a voltage to accelerate ions generated by corona discharge induced between the third discharge electrode **22** and the control electrode **32** and to induce corona discharge between the third discharge electrode **22** and the control electrode **32**.

The power supply circuit **42** has a first output terminal V_0 and a second output terminal V_1. The first output terminal V_0 of the power supply circuit **42** is connected through wiring **40***b* to the second discharge electrode **21**, the reference electrode **30**, the first output terminal V_0 of the power supply circuit **41**, the second output terminal V_1 of the power supply circuit **40** and the ground terminal GND. The second output terminal V_1 of the power supply circuit **42** is connected to the control electrode **32** through a wiring **40***d*. The second output terminal V_1 and the case **10** are insulated from each other, and the first output terminal V_0 and the case **10** are insulated from each other.

The power supply circuit **42** can output not only the output voltage of equal to or greater than −6 kV and equal to or less than 6 kV, but also the output voltage of −6 kV or less and the output voltage of than 6 kV or more. Also, the power supply circuit **41** can output the voltage having a rectangular waveform.

As described above, the ionic wind delivery device of the present embodiment has the three-step electrode-pair structure in which the electrode pair made of the first discharge electrode **20** and the reference electrode **30**, the electrode pair made of the second discharge electrode **21** and the control electrode **31**, and the electrode pair made of the third discharge electrode **22** and the control electrode **32** are connected in series.

As shown in FIG. **6**, the ionic wind delivery device of the present embodiment controls the power supply circuits **40**, **41**, **42** so that the output voltage of the power supply circuit **40** is switched between −3 kV and −2 kV, the output voltage of the power supply circuit **41** is switched between 0 V and 3 kV, and the output voltage of the power supply circuit **42** is switched between 0 V and 6 kV.

In the present embodiment, the advantageous effects similar to the first embodiment can be achieved by the structures that are common to the first embodiment.

The ionic wind delivery device of the present embodiment includes the control electrode **32** that is arranged on the delivery path of the ionic wind of ions generated by corona discharge induced between the second discharge electrode **21** and the control electrode **31**, and the third discharge electrode **22** that is arranged between the control electrode **31** and the control electrode **32**. The ionic wind delivery device of the present embodiment further includes the power supply circuit **42** that outputs the voltage to accelerate the ions generated by corona discharge induced between the third discharge electrode **22** and the control electrode **32**, and to induce the corona discharge between the third discharge electrode **22** and the control electrode **32**.

In such a configuration, further, the ions generated by the corona discharge induced between the third discharge electrode **22** and the control electrode **32** can be accelerated, as well as the corona discharge can be induced between the third discharge electrode **22** and the control electrode **32**.

The ionic wind delivery device of the present embodiment has a case **10** that accommodates the control electrode **32** and has a jet nozzle **12**. The jet nozzle **12** emits out the ionic wind of ions generated by the corona discharge induced between the first discharge electrode **20** and the reference electrode **30** as a jet stream. Also, the jet nozzle **12** also emits out the ionic wind of ions generated by the corona discharge induced between the second discharge electrode **21** and the control electrode **31**. Further, the jet nozzle **12** emits out the ionic wind of ions generated by the corona discharge induced between the third discharge electrode **22** and the control electrode **32**.

The ionic wind delivery device of the present embodiment has a control unit **50**. The control unit **50** controls the power supply circuit **40** to switch the output voltage of the power supply circuit **40** between a voltage that does not induce corona discharge between the first discharge electrode **20** and the reference electrode **30**, and a voltage that induces corona discharge between the first discharge electrode **20** and the reference electrode **30**. The control unit **50** controls the power supply circuit **41** to switch the output voltage of the power supply circuit **41** between a voltage that does not induce corona discharge between the second discharge electrode **21** and the control electrode **31**, and a voltage that induces corona discharge between the second discharge electrode **21** and the control electrode **31**. In addition, the control unit **50** controls the power supply circuit **42** to switch the output voltage of the power supply circuit **42** between a voltage that does not induce coronal discharge between the third discharge electrode **22** and the control electrode **32**, and a voltage that induces coronal discharge between the third discharge electrode **22** and the control electrode **32**.

Therefore, the ionic wind of negative ions generated by the corona discharge induced between the third discharge electrode **22** and the control electrode **32** can be emitted out as a jet stream from the jet nozzle **12**, together with the ionic wind of negative ions generated by the corona discharge induced between the second discharge electrode **21** and the control electrode **31**.

The control unit **50** controls the power supply circuit **42** to switch the output voltage to the voltage that does not induce the corona discharge between the third discharge electrode **22** and the control electrode **32** in the entirety of a period of time in which the output voltage of the power supply circuit **41** is switched and kept to the voltage that does not induce the corona discharge between the second discharge electrode **21** and the control electrode **31**.

The control unit **50** controls the power supply circuit **42** to switch the output voltage to the voltage that induces the corona discharge between the third discharge electrode **22** and the control electrode **32** in the entirety of a period of time in which the output voltage of the power supply circuit **41** is switched to and kept at the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**.

As described above, the control unit **50** performs control to induce the corona discharge between the second discharge electrode **21** and the control electrode **31** and to induce the corona discharge between the third discharge electrode **22** and the control electrode **32**, in the entirety of the period of time in which the output voltage of the power supply circuit **42** is switched to and kept at the voltage that induces the corona discharge between the third discharge electrode **22** and the control electrode **32**. Therefore, a stronger jet stream can be emitted out from the jet nozzle **12** of the case **10**.

The control unit **50** controls the power supply circuit **40** to switch the output voltage to the voltage that does not induce the corona discharge between the first discharge electrode **20** and the reference electrode **30** in the entirety of a period of time in which the output voltage of the power supply circuit **41** is switched to and kept at the voltage that does not induce the corona discharge between the second discharge electrode **21** and the control electrode **31**. The control unit **50** controls the power supply circuit **40** to switch the output voltage to the voltage that induces the corona discharge between the first discharge electrode **20** and the reference electrode **30** in the entirety of a period of time in which the output voltage of the power supply circuit **41** is switched to and kept at the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**.

In such a configuration, since the corona discharge is further induced between the second discharge electrode **21** and the control electrode **31** in the entirety of the period of time in which the output voltage of the power supply circuit **41** is switched to and kept at the voltage that induces the corona discharge between the second discharge electrode **21** and the control electrode **31**, the stronger jet stream can be emitted out from the jet nozzle **12** of the case **10**.

Fifth Embodiment

An ionic wind delivery device according to a fifth embodiment will be described. The ionic wind delivery device of the present embodiment has the same structure as the ionic wind delivery device of the fourth embodiment described above. In the ionic wind delivery device of the fourth embodiment, as shown in FIG. **9**, an output voltage of the power supply circuit **41** is switched between 0 V and 3 kV, and an output voltage of the power supply circuit **42** is switched between 0 V and 6 kV. The ionic wind delivery device of the present embodiment is different from the ionic wind delivery device of the fourth embodiment on a point that the output voltage of the power supply circuit **41** is switched between −3 kV and +3 kV, and the output voltage of the power supply circuit **42** is switched between −6 kV and +6 kV, as shown in FIG. **10**.

A control unit **50** of the present embodiment controls the power supply circuit **40** to switch the output voltage of the power supply circuit **40** to a voltage that induces corona discharge between the first discharge electrode **20** and the reference electrode **30**. At the same time, the control unit **50** controls the power supply circuit **41** to switch the output voltage of the power supply circuit **41** to a voltage that induces corona discharge between the second discharge electrode **21** and the control electrode **31**. Also at the same time, the control unit **50** controls the power supply circuit **42** to switch the output voltage of the power supply circuit **42** to a voltage that induces corona discharge between the third discharge electrode **22** and the control electrode **32**.

Therefore, the following operation will be implemented. Firstly, corona discharge occurs between the first discharge electrode **20** and the reference electrode **30**, between the second discharge electrode **21** and the control electrode **31**, and between the third discharge electrode **22** and the control electrode **32**. Further, the ionic wind of ions generated by the corona discharge is emitted out as a jet stream from the jet nozzle **12**. Thereafter, the control unit **50** performs two predetermined controls before controlling the power supply circuit **42** again to output the voltage that induces the corona discharge between the third discharge electrode **22** and the control electrode **32**. The two predetermined controls are performed simultaneously. One of the two predetermined controls is control of the power supply circuit **42** to output the voltage to move ions present between the control electrode **31** and the control electrode **32** toward the control electrode **31**. The other of the two predetermined controls is control of the power supply circuit **41** to output the voltage to move ions present between the reference electrode **30** and the control electrode **31** toward the reference electrode **30**.

In such a configuration, negative ions are moved and accumulated as the ions present between the control electrode **31** and the control electrode **32** are urged and returned toward the control electrode **31**. Also, the negative ions are moved and accumulated as the ions present between the reference electrode **30** and the control electrode **31** are urged and returned toward the reference electrode **30**.

As such, when the output voltage of the power supply circuit **41** is controlled again so as to accelerate the negative ions generated by the corona discharge toward the jet nozzle **12**, these negative ions are also accelerated while moving toward the control electrodes **31**, **32**. As a result, a larger ionic wind is generated, and this ionic wind is emitted out from the jet nozzle **12** as a jet stream. That is, the velocity of the jet stream emitted out from the jet nozzle **12** can be increased, as compared with the jet stream generation device of the fourth embodiment described above.

Other Embodiments

(1) In each of the embodiments described hereinabove, the corona discharge is induced between the first discharge electrode **20** and the reference electrode **30** as the output voltage of the power supply circuit **40** is controlled such that the potential of the first discharge electrode **20** is lower than the potential of the reference electrode **30**. As another example, the corona discharge may be induced between the first discharge electrode **20** and the reference electrode **30** by controlling the output voltage of the power supply circuit **40** such that the potential of the reference electrode **30** is lower than the potential of the first discharge electrode **20**.

(2) In each of the embodiments described hereinabove, the discharge electrodes **20**, **21**, **22** each have the end portion **20***a* with the needle shape. As another example, as shown in FIG. **11**, the discharge electrode may be provided by a narrow wire. In this case, for example, the narrow wire may be arranged to be orthogonal to a direction along an axis of the case **10**.

(3) In each of the embodiments described hereinabove, the second discharge electrode **21** and the reference electrode **30** have the same potential, and the third discharge electrode **22** and the control electrode **31** have the same potential. As another example, the second discharge electrode **21** and the reference electrode **30** may have substantially a same potential. Likewise, the third discharge electrode **22** and the control electrode **31** may have substantially a same potential.

(4) In the second to fifth embodiments described hereinabove, the tubular jet nozzle **12** is exemplified as a jet opening. As another example, the jet opening may be provided by an open hole.

(5) In the second and third embodiments described hereinabove, the discharge electrodes **20**, **21**, the reference electrode **30**, and the control electrode **31** are accommodated in the case **10**. As another example, the discharge electrodes **20**, **21** and the reference electrode **30** may be arranged outside of the case **10** as long as the control electrode **31**, which is on the last stage, is accommodated in the case **10**.

(6) In the fourth and fifth embodiments described hereinabove, the discharge electrodes **20**, **21**, **22**, the reference electrode **30** and the control electrodes **31**, **32** are accommodated in the case **10**. As another example, the discharge electrodes **20**, **21**, **22**, the reference electrode **30**, and the control electrodes **31** may be arranged outside of the case **10** as long as the control electrode **32**, which is on the last stage, is accommodated in the case **10**.

(7) In each of the embodiments described hereinabove, an aroma unit that has a plate emitting a fragrant component by such as aroma oil may be provided in the opening **13***a* of the case **10** or inside of the case **10**. In such a case, since the aroma unit has a plate emitting the fragrant component, it is possible to emit the fragrant component from the jet nozzle **12**.

(8) In each of the embodiments described hereinabove, the jet stream generation device is exemplarily installed to a meter or the like of a vehicle so as to produce a jet stream toward a face of a passenger of the vehicle to thereby improve comfort. As another example, the ionic wind delivery device may be configured to produce a jet stream of cold air or warm air toward a face or the like of a passenger of a vehicle, for the purpose of air-conditioning. In this case, for example, the ionic wind delivery device may be configured to draw cold air or warm air generated by an air conditioning apparatus from an opening **13***a* of the case **10**.

(9) In each of the embodiments described hereinabove, the jet stream generation device is exemplarily installed to a meter or the like of a vehicle so as to emit a jet stream toward a face of a passenger of a vehicle. As another example, the jet stream generation device may be configured to emit a jet stream of air having high humidity toward passenger's face or the like of a vehicle. In this case, for example, the jet stream generation device may be configured to draw air with high humidity generated by a humidifier from the opening **13***a* of the case **10**.

(10) In each of the embodiments described hereinabove, the jet stream generation device is exemplarily installed to a meter or the like of a vehicle so as to produce a jet stream toward a passenger's face of a vehicle. As another example, the jet stream generation device may be provided for each of passengers on the vehicle seats so as to individually produce a jet stream toward each passenger.

(11) In each of the embodiments described hereinabove, the jet stream generation device is exemplarily installed to a meter or the like of a vehicle so as to emit a jet stream toward a passenger's face of a vehicle. As another example, the jet

stream generation device may be installed to a ceiling of a vehicle compartment, a steering wheel, a headrest or the like. The jet stream generation device may have a fixing portion to enable the jet stream generation device to be easily fixed to a meter of a vehicle, a ceiling of a vehicle compartment, a steering wheel, a headrest, or the like.

(12) In the fourth and fifth embodiments described hereinabove, the timing to switch the output voltage of the power supply circuit **40** and the timing to switch the output voltage of the power supply circuit **41** are synchronized. Further, the timing to switch the output voltage of the power supply circuit **40** and the timing to switch the output voltage of the power supply circuit **42** are synchronized. However, it is not always necessary to synchronize these switching timings. For example, the timing to switch the output voltage of the power supply circuit **41** may be slightly retarded from the timing to switch the output voltage of the power supply circuit **40**. In addition, the timing to switch the output voltage of the power supply circuit **42** may be slightly retarded from the timing to switch the output voltage of the power supply circuit **40**. Furthermore, the timing to switch the output voltage of the power supply circuit **42** may be slightly retarded from the timing to switch the output voltage of the power supply circuit **40**.

In such a case, the operation may be modified from those of the fourth and fifth embodiments as follows. Hereinafter, the voltage that induces corona discharge between the first discharge electrode **20** and the reference electrode **30** is referred to as a first strong voltage. The voltage that does not induce the corona discharge between the first discharge electrode **20** and the reference electrode **30** is referred to as a first weak voltage.

The voltage that induces corona discharge between the second discharge electrode **21** and the control electrode **31** is referred to as a second strong voltage. The voltage that does not induce the corona discharge between the second discharge electrode **21** and the control electrode **31** is referred to as a second weak voltage.

The voltage that induces corona discharge between the third discharge electrode **22** and the control electrode **32** is referred to as a third strong voltage. The voltage that does not induce the corona discharge between the third discharge electrode **22** and the control electrode **32** is referred to as a third weak voltage.

In the entirety of a first period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first weak voltage, the second weak voltage and the third weak voltage, respectively. In the entirety of a second period of time subsequent to the first period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first strong voltage, the second weak voltage, and the third weak voltage, respectively. In the entirety of a third period of time subsequent to the second period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first strong voltage, the second strong voltage, and the third weak voltage, respectively.

In the entirety of a fourth period of time subsequent to the third period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first strong voltage, the second strong voltage, and the third strong voltage, respectively. In the entirety of a fifth period of time subsequent to the fourth period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first weak voltage, the second strong voltage, and the third strong voltage, respectively.

In the entirety of a sixth period of time subsequent to the fifth period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first weak voltage, the second weak voltage, and the third strong voltage, respectively. In the entirety of a seventh period of time subsequent to the sixth period of time, the control unit **50** controls the output voltages of the power supply circuits **40**, **41**, **42** to the first weak voltage, the second weak voltage, and the third weak voltage, respectively.

The control unit **50** controls the output voltage of the power supply circuit **42** to the third weak voltage, in a part of the periods of time in which the output voltage of the power supply circuit **41** is controlled to the second weak voltage (that is, in the first period of time, the second period of time and the seventh period of time among the first period of time, the second period of time, the sixth period of time and the seventh period of time). The control unit **50** controls the output voltage of the power supply circuit **42** to the third strong voltage, in a part of the periods of time in which the output voltage of the power supply circuit **41** is controlled to the second strong voltage (that is, in the fourth period of time and the fifth period of time among the third period of time, the fourth period of time and the fifth period of time).

The control unit **50** controls the output voltage of the power supply circuit **40** to the first weak voltage, in a part of the periods of time in which the output voltage of the power supply circuit **41** is controlled to the second weak voltage (that is, in the first period of time, the sixth period of time and the seventh period of time among the first period of time, the second period of time, the sixth period of time, and the seventh period of time). The control unit **50** controls the output voltage of the power supply circuit **40** to the first strong voltage, in a part of the periods of time in which the output voltage of the power supply circuit **41** is controlled to the second strong voltage (that is, in the third period of time and the fourth period of time among the third period of time, the fourth period of time and the fifth period of time).

As described above, the period of time in which the output voltage of the power supply circuit **40** is the first strong voltage and the period of time in which the output voltage of the power supply circuit **41** is the second strong voltage overlap with each other at least at a part. Also, the period of time in which the output voltage of the power supply circuit **40** is the first weak voltage and the period of time in which the output voltage of the power supply circuit **41** is the second weak voltage overlap with each other at least at a part. There are also true for the second embodiment.

As described above, the period of time in which the output voltage of the power supply circuit **41** is the second strong voltage and the period of time in which the output voltage of the power supply circuit **42** is the third strong voltage overlap with each other at least at a part. Also, the period of time in which the output voltage of the power supply circuit **41** is the second weak voltage and the period of time in which the output voltage of the power supply circuit **42** is the third weak voltage overlap with each other at least at a part.

As described above, the period of time in which the output voltage of the power supply circuit **40** is the first strong voltage and the period of time in which the output voltage of the power supply circuit **42** is the third strong voltage overlap with each other at least at a part. Also, the period of time in which the output voltage of the power supply circuit **40** is the first weak voltage and the period of time in which the output voltage of the power supply circuit **42** is the third weak voltage overlap with each other at least at a part.

(13) In each of the fourth and fifth embodiments described hereinabove, the electrode pairs are connected in series in three stages. As another example, the electrode pairs of more than four stages may be connected in series.

The present disclosure is not limited to the embodiments described hereinabove, but can be suitably modified. The embodiments described hereinabove are not irrelevant to each other, but can be suitably combined as long as those can be combined without discrepancy. In the embodiments described hereinabove, the number, the value, or the quantity of respective structural elements, and any numeric values such as the range of values are not limited to those described unless those are explicitly described as necessary or those need to be explicitly limited to specific values. In the embodiments described hereinabove, the material, the shape, or the positional relationship of respective structural elements is not limited to those described unless those are explicitly described or those need to be explicitly limited to the specific material, the shape or the positional relationship.

What is claimed is:

1. An ionic wind delivery device comprising:

a first discharge electrode;

a reference electrode that is arranged separate from the first discharge electrode;

a first power supply circuit that is configured to output a voltage to induce a corona discharge between the first discharge electrode and the reference electrode;

a control electrode that is arranged on a delivery path of an ionic wind of ions that are generated by the corona discharge induced between the first discharge electrode and the reference electrode;

a second discharge electrode that is arranged between the reference electrode and the control electrode; and

a second power supply circuit that is configured to output a voltage that accelerates the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode and induces a corona discharge between the second discharge electrode and the control electrode, wherein

the first power supply circuit and the second power supply circuit are configured to be controlled in such a manner that:

the first power supply circuit is switched to output the voltage that induces the corona discharge between the first discharge electrode and the reference electrode and the second power supply circuit is switched to output the voltage that induces the corona discharge between the second discharge electrode and the control electrode, so that an ionic wind of ions that are generated by the corona discharge induced between the first discharge electrode and the reference electrode and the corona discharge induced between the second discharge electrode and the control electrode is emitted as a jet stream; and

after the ionic wind is emitted, and before the second power supply circuit is switched again to output the voltage that induces the corona discharge between the second discharge electrode and the control electrode, the second power supply circuit is controlled to output a voltage so as to move ions present between the reference electrode and the control electrode toward the reference electrode.

2. The ionic wind delivery device according to claim **1**, comprising:

a case that accommodates at least the control electrode, and has a jet opening to emit the ionic wind of the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode and the corona discharge induced between the second discharge electrode and the control electrode; and

a control unit that is configured to switch an output voltage of the second power supply circuit between a voltage that prohibits the corona discharge between the second discharge electrode and the control electrode and the voltage that induces the corona discharge between the second discharge electrode and the control electrode.

3. The ionic wind delivery device according to claim **2**, wherein

the control unit controls the first power supply circuit to output a voltage that prohibits the corona discharge between the first discharge electrode and the reference electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that prohibits the corona discharge between the second discharge electrode and the control electrode, and

the control unit controls the first power supply circuit to output the voltage that induces the corona discharge between the first discharge electrode and the reference electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that induces the corona discharge between the second discharge electrode and the control electrode.

4. The ionic wind delivery device according to claim **2**, wherein

the control unit switches an output voltage of the first power supply circuit to the voltage that induces the corona discharge between the first discharge electrode and the reference electrode and switches the output voltage of the second power supply circuit to the voltage that induces the coronal discharge between the second discharge electrode and the control electrode, so that the ionic wind of the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode and the corona discharge induced between the second discharge electrode and the control electrode is emitted out from the jet opening as a jet stream, and

after the ionic wind is emitted out from the jet opening, and before the control unit again controls the second power supply circuit to output the voltage that induces the corona discharge between the second discharge electrode and the control electrode, the control unit controls the second power supply circuit to output a voltage so as to move the ions present between the reference electrode and the control electrode toward the reference electrode.

5. The ionic wind delivery device according to claim **1**, wherein

the control electrode is referred to as a first control electrode,

the ionic wind delivery device further comprising:

a second control electrode that is arranged on a delivery path of the ionic wind of the ions generated by the corona discharge induced between the second discharge electrode and the first control electrode;

a third discharge electrode that is arranged between the first control electrode and the second control electrode; and

a third power supply circuit that is configured to output a voltage to accelerate ions generated by a corona discharge induced between the third discharge electrode and the second control electrode and to induce the corona discharge between the third discharge electrode and the second control electrode.

6. The ionic wind delivery device according to claim **5**, further comprising:

a case that accommodates at least the second control electrode, and has a jet opening to emit an ionic wind of the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode, the corona discharge induced between the second discharge electrode and the first control electrode, and the corona discharge induced between the third discharge electrode and the second control electrode; and

a control unit that is configured to switch an output voltage of the second power supply circuit between a voltage that prohibits the corona discharge between the second discharge electrode and the first control electrode and the voltage that induces the corona discharge between the second discharge electrode and the first control electrode, and to switch an output voltage of the third power supply circuit between a voltage that prohibits the corona discharge between the third discharge electrode and the second control electrode and a voltage that induces the corona discharge between the third discharge electrode and the second control electrode.

7. The ionic wind delivery device according to claim **6**, wherein

the control unit controls the output voltage of the third power supply circuit to the voltage that prohibits the corona discharge between the third discharge electrode and the second control electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that prohibits the corona discharge between the second discharge electrode and the first control electrode, and

the control unit controls the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that induces the corona discharge between the second discharge electrode and the first control electrode.

8. The ionic wind delivery device according to claim **7**, wherein

the control unit further controls an output voltage of the first power supply circuit to a voltage that prohibits the corona discharge between the first discharge electrode and the reference electrode at least in the part of the period of time in which the output voltage of the second power supply circuit is controlled to the voltage that prohibits the corona discharge between the second discharge electrode and the control electrode, and

the control unit controls the output voltage of the first power supply circuit to the voltage that induces the corona discharge between the first discharge electrode and the reference electrode at least in the part of the period of time in which the output voltage of the second power supply circuit is controlled to the voltage that induces the corona discharge between the second discharge electrode and the control electrode.

9. The ionic wind delivery device according to claim **7**, wherein

the control unit switches an output voltage of the first power supply circuit to the voltage that induces the corona discharge between the first discharge electrode and the reference electrode, switches the output voltage of the second power supply circuit to the voltage that induces the corona discharge between the second discharge electrode and the first control electrode, and switches the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode, so that the ionic wind of the ions generated by the corona discharges induced between the first discharge electrode and the reference electrode, between the second discharge electrode and the first control electrode, and between the third discharge electrode and the second control electrode is emitted out from the jet opening as a jet stream, and

after the ionic wind is emitted out from the jet opening, and before the control unit again controls the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode, the control unit controls the third power supply circuit to output a voltage so as to move ions present between the first control electrode and the second control electrode toward the first control electrode, and the second power supply circuit to output a voltage so as to move ions present between the reference electrode and the first control electrode toward the reference electrode.

10. An ionic wind delivery device comprising:

a first discharge electrode;

a reference electrode that is arranged separate from the first discharge electrode;

a first power supply circuit that is configured to output a voltage to induce a corona discharge between the first discharge electrode and the reference electrode;

a first control electrode that is arranged on a delivery path of an ionic wind of ions that are generated by the corona discharge induced between the first discharge electrode and the reference electrode;

a second discharge electrode that is arranged between the reference electrode and the first control electrode;

a second power supply circuit that is configured to output a voltage that accelerates the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode and induces a corona discharge between the second discharge electrode and the first control electrode;

a second control electrode that is arranged on a delivery path of an ionic wind of ions generated by the corona discharge induced between the second discharge electrode and the first control electrode;

a third discharge electrode that is arranged between the first control electrode and the second control electrode;

a third power supply circuit that is configured to output a voltage to accelerate ions generated by a corona discharge induced between the third discharge electrode and the second control electrode and to induce the corona discharge between the third discharge electrode and the second control electrode;

a case that accommodates at least the second control electrode, and has a jet opening to emit an ionic wind of the ions generated by the corona discharge induced between the first discharge electrode and the reference electrode, the corona discharge induced between the second discharge electrode and the first control electrode, and the corona discharge induced between the third discharge electrode and the second control electrode; and a control unit that is configured to switch an output voltage of the second power supply circuit between a voltage that prohibits the corona discharge between the second discharge electrode and the first control electrode and a voltage that induces the corona discharge between the second discharge electrode and the first control electrode, and to switch an output voltage of the third power supply circuit between a voltage that prohibits the corona discharge between the third discharge electrode and the second control electrode and a voltage that induces the corona discharge between the third discharge electrode and the second control electrode, wherein

the control unit controls the output voltage of the third power supply circuit to the voltage that prohibits the corona discharge between the third discharge electrode and the second control electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that prohibits the corona discharge between the second discharge electrode and the first control electrode,

the control unit controls the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode at least in a part of a period of time in which the output voltage of the second power supply circuit is controlled to the voltage that induces the corona discharge between the second discharge electrode and the first control electrode,

the control unit switches an output voltage of the first power supply circuit to a voltage that induces the corona discharge between the first discharge electrode and the reference electrode, switches the output voltage of the second power supply circuit to the voltage that induces the corona discharge between the second discharge electrode and the first control electrode, and switches the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode, so that an ionic wind of the ions generated by the corona discharges induced between the first discharge electrode and the reference electrode, between the second discharge electrode and the first control electrode, and between the third discharge electrode and the second control electrode is emitted out from the jet opening as a jet stream, and

after the ionic wind is emitted out from the jet opening, and before the control unit again controls the output voltage of the third power supply circuit to the voltage that induces the corona discharge between the third discharge electrode and the second control electrode, the control unit controls the third power supply circuit to output a voltage so as to move ions present between the first control electrode and the second control electrode toward the first control electrode, and the second power supply circuit to output a voltage so as to move ions present between the reference electrode and the first control electrode toward the reference electrode.

11. The ionic wind delivery device according to claim **10**, wherein

the control unit further controls the output voltage of the first power supply circuit to a voltage that prohibits the corona discharge between the first discharge electrode and the reference electrode at least in the part of the period of time in which the output voltage of the second power supply circuit is controlled to the voltage that prohibits the corona discharge between the second discharge electrode and the control electrode, and

the control unit controls the output voltage of the first power supply circuit to the voltage that induces the corona discharge between the first discharge electrode and the reference electrode at least in the part of the period of time in which the output voltage of the second power supply circuit is controlled to the voltage that induces the corona discharge between the second discharge electrode and the control electrode.

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